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and *Faust*,[60] its symbolism strongly reminds us of some of Ibsen's plays, as indicated by Bartels, the fairies dancing in the woods and the boiling kettle at once suggest Shakespeare, but no modern dramatist can produce such scenes on the stage without reminding his audience of Shakespeare. I fail to see any connection between Raimund's fairy-plays and the *Versunkene Glocke*, except that in both cases the *dramatis personæ* consist of men and fairies. Hauptmann does not show a trace of that Romantic irony which characterizes Tieck's fairy-plays, and from which Raimund is not free. But Hauptmann uses one motif which is very old, and has been used again and again in works of literature: the Tannhäuser motif. The idea underlying the legend of Tannhäuser is, to quote Böhme, this:

"der irdische jüngling, in die umarmung der elfenmaid verstrickt, entreisst sich ihr nur mit dem tode im herzen."[61]

Heinrich's longing for home, his qualms of conscience, his sudden departure from the mountains, and his return—all go back to the old Tannhäuser ballad. In one version of the ballad Venus says to Tannhäuser:

"ich han so vil der edlen zwerg,
helt die müssen dienen dir
mit stechen, singen, seitenspil."[62]

Almost the same inducements Rautendelein holds out to Heinrich. And just as in the old ballad,[63] Tannhäuser says to *Frau Venus:* "Ihr seid ein Teufelinne," so Heinrich calls Rautendelein *elbische Vettel.* The ballad even contains the suggestion that Tannhäuser spurns the hand of one of Venus's maidens, because he has another woman in mind (*Dtsch. Liederhort*, I, 42). The similarity between our play and Fouqué's *Undine* rests chiefly upon the use of this motif. Undine's character, as we have seen, may have given the poet some suggestions for Rautendelein, but I cannot see that, as Bartels thinks, the *Nickelmann* is descended from *Ohm Kühleborn;* as they are both spirits of the water, there must necessarily be some resemblance. The *Nickelmann's* beautiful lines about the human race are certainly not borrowed from Fouqué's *Undine.* Grillparzer's *Melusina*, to which Mr. Schütze ascribes so much influence on Hauptmann's play,[64] has no connection with the play except that it also makes use of this motif; that explains all the similarities. Hauptmann's scene is laid in the Giant Mountains.[65] The scenery in *Melusina* shows a certain resemblance which seems to be entirely accidental; it lacks one of the most important points, the hut (cf. the passage from Grimm's tales quoted above).

Besides the Tannhäuser legend with its variants,[66] there are numerous popular traditions in which elfish beings, male and female, enter into intimate relations with human beings. The end is almost invariably an unhappy one for both sides.[67]

It cannot be denied that the poet may have received suggestions from literary works besides those referred to, but they are not of great importance. Hauptmann's symbolism goes back in some degree to Ibsen, but on the whole there is no doubt that the poet is far more indebted to German folk-lore than to all the works of literature combined.

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SPEECH CURVES.

I

In a field of investigation so little explored as that of the curves of speech it is necessary to have combined efforts of many workers in order to properly handle the material obtained. It is particularly desirable that those trained in observations of the sounds of speech, and familiar with their history, should co-operate with those using experimental methods. Curves of speech, when carefully and correctly obtained, contain far more information than any one worker can abstract from them. In recognition of this fact a number of the curves traced off at Yale University will be published in the Mod. Lang. Notes, with such statements concerning the manner of obtaining them, and the methods of measurement, as will make them available for investigation by any one who is willing to study them.

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[60] Cf. Henkel, *Zschr. f. d. dtsch. Unterricht, XIII*, 258.

[61] Erk-Böhme, *Dtsch. Liederhort*, I, 51.

[62] Grässe, *Der Tannhäuser und Ewige Jude*, Dresden, 1861, p. 33.

[63] Erk-Böhme, *ibid.*, No. 17a.

[64] *Americ. German.* III, 68 ff.

[65] Cf. Mod. Lang. Notes, xv, 353.

[66] Cf. Grässe, *D. Tannhäuser und Ewige Jude*, p. 9.

[67] Cf. Grimm, *Irische Elfenmärchen*, p. xcvii, 4.

The laboratory at Yale University is also willing to supply curves directly to investigators. Each investigator will receive a definite portion of a record with its translation. This portion will not be given to any one else, and the publication of it will be postponed to a definite date to permit the investigator to complete his work and publish the result with the curve.

"Rip Van Winkle's Toast," by Joseph Jefferson, is ready; the publication will occur on October 1, 1901. "A Speech on Forefather's Day," by Chauncey Depew, will be ready in a few weeks. This will be followed by "Die Lorelei" and "Der Fichterbaum" by William L. Elterich a "Talk on Money" by George Graham, and other records of prose, verse, song and instrumental music. French,Spanish, Italian, Japanese and other records will be added during the coming summer.

The machine in the Yale laboratory will be placed at the disposal of investigators for tracing off any desired gramophone plates. Three absolutely unused copies of any plate from the gramophone (or zonophone) list must be received at the laboratory. The tracing will be done whenever the machine is at liberty, and the results will be forwarded to the investigator. The Yale laboratory will sustain the quite considerable expense of caring for the tracing, reserving in compensation certain rights of publication.

Duplicates of the entire tracing machine itself will be furnished at the actual expenditure for labor and materials. In its present form the cost will amount to about $250; with the addition of jewelled bearings for all the pivots this will be increased by $100 or $150. A complete description of the machine, with detailed drawings will soon be published; this will render its duplication possible in any fine machine-shop but the cost will be much greater owing to the special training needed for its construction.

Similar arrangements may be made for tracings from the French celluloid phonograph of Lioret (18 rue Thibaud, Paris). The tracing machine for these cylinders is now in process of construction on a grant from the Elizabeth Thompson Science Fund; the great difficulties already encountered indicate that it will not be finished before summer.

The interpretation of the speech curves procedes in the following way:

The words spoken by the gramophone plate are noted on paper with an indication of the relative lengths of the pauses. The pauses are classed as short, medium and long.

The first vibrations on the record are taken as representing the first word on the plate. The first long straight line on the record is taken as the first pause. Then the successive sounds between the beginning and the first pause are assigned to the successive groups of vibrations. The method is followed for succeeding groups of sounds between pauses. Considerable help is obtained by a familiarity with the peculiarities of speech curves.

The curves reproduced in this issue of the Notes are traced from a gramophone plate containing the *Sad Story of the Death and the Burial of Poor Cock Robin*, by William F. Hooley. The sound curve on this plate was first traced off with not very great enlargement; these curves are known as *Cock Robin, Series I.* Some of the results have been published in *Stud. Yale Psych Lab.*, vii.

A development of the original apparatus made it possible to obtain greater enlargement, and the same plate was again traced off; the results are known as *Cock Robin, Series II.* The first published selection from this series is that given in this issue; it has been designated as *Cock Robin, Series II, Block I.* The selection includes *saw him* from *Who saw him die?; bow* from *With my bow and arrow; shroud* from *Who'll make his shroud?; sparrow* from *I, said the sparrow;* and *draw your* from the introduction *Now, children, draw your little chairs nearer.*

The curves given on pages 78, 79 belong to one block. The line reads across the two pages from left to right; thus, the sounds *aw im* of *saw him* read along the first line from left to right across Block Iᴀ and then across Block Iʙ. The sound *ow* of *bow* begins with the second line of the Block Iᴀ, reads over the second line of Block Iʙ, and then over the third line of Block Iᴀ, ending in the third line of Block Iʙ.

The speech curves would naturally run along horizontal lines. The slow fluctuations seen in the records are due to irregularities in feeding the gramophone plate sidewise.

They in no way affect the accuracy of the records; in making measurements, however, the ruler should always be horizontal.

To interpret the details of a sound the grouping of the vibrations is first noticed. In a series of groups of the same general form each group may usually be considered as arising from one puff of the vocal cords. The minor vibrations arise from the vibrations of the resonating cavities and from the overtones of the cords.

Many of the main features of the speech curves can be obtained by inspection without measurement; very much more can be obtained by simple measurements.

Long distances may be measured by millimeter scales; the tenths of a millimeter may be estimated by the eye. Finer measurements may be made with a scale graduated in tenths of a millimeter;[1] the work is done with a watchmaker's eyeglass, or under a magnifying glass. The calculations are all done by books of tables.[2] The investigator should become familiar with various books containing extensive multiplication tables, tables of reciprocals, etc. A Chinese abacus is also very convenient in adding.

The speech curves are frequently of such a nature that the period of the cord tone may be found by measuring the distance between two like points in two successive groups of vibrations.

The distance in millimeters is translated into time according to the equation beneath each block. Thus, the distance between the two high points in the last vibration in the fourth line on Block I^A is 3.2^{mm}; at 1^{mm} for 0.0016^s (use Zimmermann's table for 16), this gives a period of 0.01536^s for the cord vibrations at that instant. A period of 0.01536^s is the same as a frequency of $1 \div 0.01536$ (use Barlow) or 65.1. For all the curves except that of *draw your* the relation is $1^{mm} = 0.0016^s$; for this curve it is $1^{mm} = 0.0007^s$.

The periods of the smaller, or resonance vibrations can frequently be obtained by direct measurement. This occurs most readily when these vibrations are of a simple form.

The problem of finding all the tones in the speech sounds is one of unsurmounted difficulty. Approximations can be made by use of the Fourier analysis, the instructions for performing which will be given on a future occasion. Some new methods of analysis are being developed. The importance of studying the complete set of tones and their continual change is made evident by the fact that speech is not merely a succession of tones for the larynx (or a voice melody), but is at each moment a more or less harmonized complexity of tones from the larynx and the pharyngeal and buccal cavities. Each tone in the harmony changes from instant to instant; its changes are determined not only by its preceding course, but also by relations to other preceding and coincident tones. An observation on the relation of change between the cord tone and the lower resonance tone in the diphthong *ai* has been stated in *Stud. Yale Psych. Lab.*, vii, 57.

The following account is intended to show how some of the facts contained in a speech curve may be extracted from it. The curve at first sight is no more intelligible than a line of Chinese ideographs. The knowledge of the speech sounds to which a certain portion of a curve belongs gives the purpose of the curve but affords little information concerning its character. A careful study of the sound by the ear reveals some of the grosser characters of the sound, but cannot indicate any of the finer details that lie before the eye in the complexities of the curve. The meaning of these details—the very essentials of the speech sound—is not apparent at first observation; only by patient and persistent unraveling of the tangled curve is an inkling of it obtained.

saw him. The words are run together in speech on the gramophone so that the result is rather *såim* than *saw him*, the *h* not being heard, and the two vowels being run together like a diphthong. The record shows no traces of the *s*. The first vibrations of the curve differ from the rest, and show changing relations between the resonance (or mouth) tone and the cord tone; they indicate that the cords have begun to vibrate while the mouth is still changing from the *s* position to the *å* position. After this the grouping of the vibrations in threes indicates a cord tone with a resonance (or mouth) tone a duodecime higher; this general relation is maintained throughout the diphthong. That still other resonance tones are present is indicated by the subordinate modifications of the small vibrations. The sound *å* increases slowly in intensity, but diminishes again as it changes into *i* (beginning of Block I_B). The *i* is quite strong but falls quickly as the sound changes to *m*. The *m* vibrations slowly fade away. The relations between *å* and *i* in this diphthong somewhat resemble those between *a* and *i* in *ai* discussed in *Stud. Yale Psych. Lab.* vii; they differ in the fall of amplitude at the end of *å* before the *i* begins, whereby the separation of the elements of the double sound is slightly marked.

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[1] The Société Genevoise makes a "petite echelle en argentan divisé d'un coté en dixiemès de millimetres" for 20 francs. It can be readily imported through the Kny-Scheerer Co., 225 Fifth Ave., N. Y.

[2] Crelle, *Rechentafeln*, Berlin, 1857; *Calculating Tables*, First English Edition, New York, 1888.

Zimmermann, *Rechentafeln*, Berlin, 1891.

Barlow, *Tables of Squares, Cubes, Square Roots, Cube Roots, Reciprocals of all integer numbers up to 10,000.* Reprint Edition, London and New York, 1897.

The following table shows the way in which the course of the cord tone in reference to pitch is calculated. It illustrates several important principles used in computing and interpreting results.

A. Period in millimeters.	B. Period in seconds.	C. Frequency.
3.8	0.0061	167
3.8	61	167
3.9	62	161
4.0	64	156
4.0	64	156
2.6		
4.2	67	149
4.2	67	149
4.1	66	152
4.0	64	156
4.2	67	149
4.3	69	145
4.3	69	145
4.2	67	149
4.3	69	145
4.3	69	145
4.3	69	145
4.1	66	152
4.2	67	149
4.3	69	145
4.5	72	139
4.5	72	139
4.5	72	139
4.8	0.0077	130
5.0	80	125
5.1	82	122
5.0	80	125
5.1	82	122
5.2	83	120
5.1	82	122
4.7	75	133
4.6	74	135
4.7	75	133
4.8	77	130
4.7	75	133
4.4	70	143
4.5	72	139
4.5	72	139
4.5	72	139
4.7	75	133
4.5	72	139
4.7	75	133
4.5	72	139
4.6	74	135
4.4	70	143
4.6	74	135

The figures in column A give the distances in millimeters from apex to apex of the strongest vibrations in the successive groups. The measurements were made by an assistant who did not know the nature of the problem investigated. It is very important to note the following:

1. The determination of the exact point to be called the apex may be indefinite to the extent of one or two tenths of a millimeter, owing (*a*) to the roundness of the apex, (*b*) to the fact that the apex is sometimes slightly displaced by interfering resonance tones.

2. The general character of muscular action would indicate that the changes in the voice proceed with some regularity; this would indicate that the unusual figure 2.6 for the sixth period does not give the proper period at that point but shows something else.

Using Zimmermann's table for 16, the figures in column A are turned into time as shown in column B. These are the lengths of successive periods in the cord tone. Using a table of reciprocals (Barlow or Zimmermann) these are turned into the frequencies in column C.

The curve of frequency is now to be plotted. This is best done by supposing the speech curve to be laid off along the horizontal or *X* axis, so that the first vibration is at zero. Above zero the proper number of millimeters is counted upward to indicate the frequency of the cord tone at the start; this is obtained by taking the reciprocal of the duration of the first complete group of minor vibrations arising from a puff from the chords. Thus, if the duration of the first group is 0.12^s, the frequency will be 83; if 10^{mm} have been assigned to each 100 of frequency, the dot will be placed at 8.3^{mm} above the *X* axis. Above the point on the *X* axis at which the second group of vibrations would begin if the curve were laid upon it, the frequency of the cord tone at this moment is indicated by a dot at the proper height; this is obtained by taking the reciprocal of the duration of the second complete group of minor vibrations arising from a puff from the cords. In this manner a series of dots is obtained, indicating the frequency of the cord tone at a succession of movements.

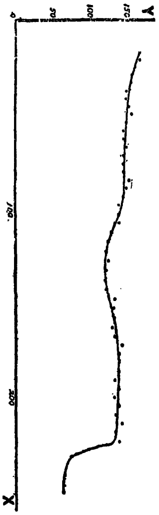

Figure I.
Curve of frequency of *saw him.*

It will be found that few sounds have a constant frequency throughout their duration. The voice is constantly sliding up and down; just these movements give character to the sounds themselves. A number of curves of frequency for *ai* in *I*, *die*, *thy*, etc., have been determined (*Stud. Yale Psych. Lab.* vii) but otherwise nothing in this line seems to have been done. The sliding of the cord tone in speech was observed by Aristoxenus.

In the diagram of frequency the successive dots might be connected by straight lines. We probably come nearer to the true curve of frequency (see 1 and 2 above) by drawing a smooth curve that evenly distributes the dots on either side. This may be done with the free hand, by means of draughtman's curves or by a flexible rubber rule; the more general reasons for this procedure may be found in works on the methods of science.[3]

Such curves of pitch plotted through a whole discourse would replace by accurate data the interesting but sketchy attempts made by the unaided ear at noting the melody of speech.

The curious interruption of the regular course of figures in the table by 2.6 arises from the fact that the series of the strongest vibrations used to mark off the groups is replaced at this point by a series arising from one of the weaker vibrations. In the first part of the curve there is some vibration of a changing character that causes a change in the moment of strongest vibration. The unusual figure indicates this latter fact and not any sudden break in the cord tone. A similar occurrence may be seen in the *o* of *bow* at the beginning of line 2 Block $\mathrm{I_B}$ and in *aw* of *draw* as indicated below.

At the start (the "glide" from *s* to ă) the smaller vibrations show a period of 0.0032^s or a frequency of 313. This resonance tone quickly changes to one of 0.0024^s period, or 417 frequency. It remains at this figure throughout most of its course but becomes 0.0028^s or 357, toward the end of å (end of left hand block). During the *i* it is 0.0032^s.

bow. The word in this case was melodious and prolonged; it might even be said to be "mellifluous." The record shows the curve of *ow.* It begins with three faint vibrations that presumably occur as the mouth begins to open. Thereafter the vibrations follow in groups of 4 with a length of 5.5 mm. decreasing slowly to 4.8 mm. at the edge of Block $\mathrm{I_A}$, this indicates a cord tone of rising pitch. The resonance tone remains practically constant at $1.5^{mm.}$ per vibration, or a period of 0.0024^s and a frequency of 417.

The amplitude rises steadily to a degree that indicates considerable loudness; it then falls rather suddenly (end of second line in Block $\mathrm{I_A}$). The vibrations beyond this point show so many peculiarities that their difficulties can best be attacked by working backward from a later point where the grouping is more regular. About one-third of the distance from the left in the second line on Block $\mathrm{I_B}$ the vibrations fall into groups having two main crests with two subordinate crests. This entire group presumably arises from one cord vibration. This conclusion is drawn because further on to its right the group gradually changes to two main crests only, a typical form for a cord tone accompanied by a resonance tone nearly an octave higher. This condition of a cord tone with an octave resonance tone is modified in the first part by higher tones that do not form an exact harmonic interval with either of the other tones; these give rise to the minor fluctuations in the first half of the curve in Block I_B. These higher tones are of changing pitch as can be seen by the steadily changing form.

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[3] Jevons, *Principles of Science*, Chap. xxii.

The puffs of air from the cords are not generally of the even nature found in sinusoid vibrations; they rather resemble more or less sharp explosions. In this sound they are not so sharply explosive as in *au* of *shroud* or *æ* of *sparrow*, yet the puff has its greatest intensity in the first part of the interval of time it occupies. Starting from the strong vibrations (middle of line 2, Block I_B), we mark off backward the alternate higher vibrations as the points of maximum for each cord puff. We thus have the vibrations in pairs; the period of the chord tone at any moment will be given by the distance between two such marked vibrations. As we go towards the left, we see that each of the vibrations of the pair shows a tendency to split up into two minor vibrations; this indicates the presence of higher resonance tones. Measurements of the periods of the cord tone show that it steadily rises in pitch from the end of Block I_A to the middle of Block I_B. They also will show that the alternate (or resonance) vibration keeps very closely at the middle of the cord period; though in the first portion it is generally a little behind the middle point. This indicates a resonance tone in general an octave higher than the cord tone, but a little lower in the first portion. The details can be brought out by measurements.

A third maximum is found in the latter portion of *bow* (third line Block I_A). It may be suggested that perhaps this vowel sound is to be considered as a tripthong. Careful listening to the gramophone plate enables the ear to hear two maxima clearly and the third faintly.

shroud. The dipthong *au* begins in the middle of line 4 on Block I_A. It is preceded by a series of vibrations whose interpretation is not quite clear. The *d* begins on line 5 at the left edge of Block I_B. The cord vibrations can be detected in the curve for the *d;* they become marked toward the end of this line, indicating the opening of the mouth after the closed *d* position.

sparrow. The *æ* of *sparrow* begins in the middle of the sixth line on Block I_A; it ends in *r* just beyond the middle of the same line in Block I_B. The *o* extends over the remainder of this line and the whole of the next. This *o* is quite different from that in *bow* above. The vowel is a crescendo-diminuendo sound; its amplitude rises slowly to a maxium and then falls to zero. The vowel-sound in *bow* has three maxima; the fall from the maxium is in two cases very sudden. In general the curve of the *o* of *sparrow* differs greatly from that of the *o* of *bow*, although there is some resemblance of the former to the middle portion of the latter.

draw your. The last five lines of Block I give the curve for the sounds *åiu* of the words *dråiur* expressed in print by *draw your.* The recording surface was run at about three times the speed used for the previous curves, its equation being $1^{mm.}=0.0007^{s}$. This speed is more favorable for the details of vibrations of greater amplitude but less favorable for those of less amplitude. The analysis of the curve may be approached in the following way: The vibrations in the latter portion of the eighth line of Block I_B are evidently to be grouped in threes. There is present here a cord tone with a resonance tone a duodecime above it. The last group on this line has a length of 10.2^{mm}, indicating a cord period of 0.00714^{s}, or, compressing the figure to ten-thousandths of a second, 0.0071^{s}. This gives a cord tone at this point with a frequency of 143, or d°, that is, *D* of the base cleff. Measuring backward we find that the preceding group is a little longer than this one; in fact each group is found to be a little longer than the following one. The cord tone is thus shown to be rising in pitch.

The three small vibrations that make up the last group on line 8 are nearly equal in length although the last one appears to be cut off somewhat by the following stronger vibration of the next group. The preceding group shows nothing of the cutting off. The next preceding group shows that the three small vibrations do not quite fill out the interval between the apexes of two strong vibrations selected to mark off the groups. This becomes still more evident in the further preceding groups. This condition seems to indicate that the small vibrations composing a group retain a constant period while the length of the group is changing. In confirmation of this we finally find four small vibrations instead of those in the early part of the vowel. The period of the small vibrations is approximately 0.0028^s, giving a frequency of 357 or about f^1 of the treble cleff. This is a very clear illustration of the fact that the resonance tones of vowels are independent of the cord tone in regard to pitch, and are not overtones of it as commonly supposed.

That there are still other resonance tones is indicated by minor deformations of the curve, but further information concerning them is not obtainable at present.

Proceeding onward, we find that the cord tone continues to rise. At the middle of line 9, Block I_A, the length of a group is 9.0^{mm}, giving a period of 0.0063^s or a frequency of 159; at the middle of Block I_B the length is 8.0^{mm}, the period 0.0056^s and the frequency 179. The tone now rises more slowly. At the middle of line 10, Block I_A, the length is 7.5^{mm}, the period 0.0053^s, and the frequency 189. Beyond this point the tone remains nearly constant.

In the meantime the resonance vibrations have been undergoing a change. Instead of one resonance tone, two begin to show themselves distinctly. The most powerful one appears as a fairly strong vibration at 50^{mm} (0.0035^s) after each strongest vibration in the group. Although the group shortens, this vibration remains at a nearly constant distance from the beginning, necessarily, however, approaching even closer to the vibration at the end. This "strong secondary" vibration has been observed in many cases of *a* in *ai* (*Stud. Yale Psych. Lab.*, 1889, vii, 23). In those cases it remained at a constant distance from the beginning of the group till the group became so short that it coalesced with the strongest vibration of the following group. Here the fate is different. Instead of remaining at an absolutely constant distance behind the preceding strongest vibration of the group, it gradually, but not greatly, lessens the distance till, as the cord tone becomes stationary in pitch, it ultimately occupies the middle of the group as the octave of the cord tone. But another change has taken place that is of a puzzling nature; this strong secondary gradually becomes stronger than the other vibrations in the group. This can be readily seen by checking off the strongest vibrations in line 9 as boundaries of groups beginning at the left; in the earlier portion on Block I_B it will be found that one vibration has become stronger than the ones that must be checked off as boundaries of groups.

The cord tone remains constant with a period of about 0.0053^s throughout line 10. The resonance tone at an octave above also remains unchanged. The other resonance tones that produce the small marked inflections in line 9 and line 10 gradually dies away (middle of line 10, Block I_B), leaving the vibrations grouped in pairs at the end of line 10.

In line 11 the vowel somewhat suddenly decreases in amplitude. It is followed by the weak vibrations of the weak (but not very short!) *i* that precedes *u* in *your*.

Line 12 shows the latter portion of *your*; the curve is not completed.

Probably enough has been said to show the manner in which the analysis of speech curves proceeds. It is to be hoped that other workers may take up these curves and give them interpretations and measurements; it is desirable that results obtained should be brought to the notice of MOD. LANG. NOTES. The results of work at Yale will be summarized in these NOTES.

E. W. SCRIPTURE.

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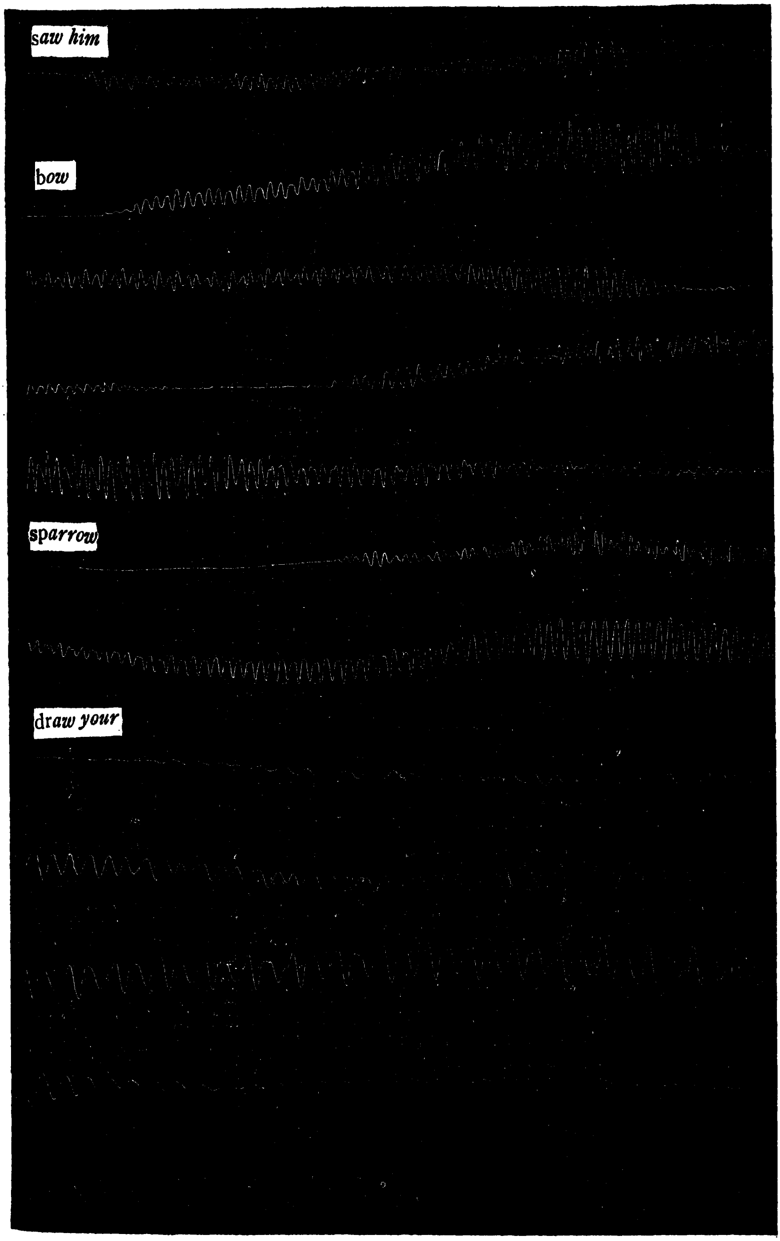
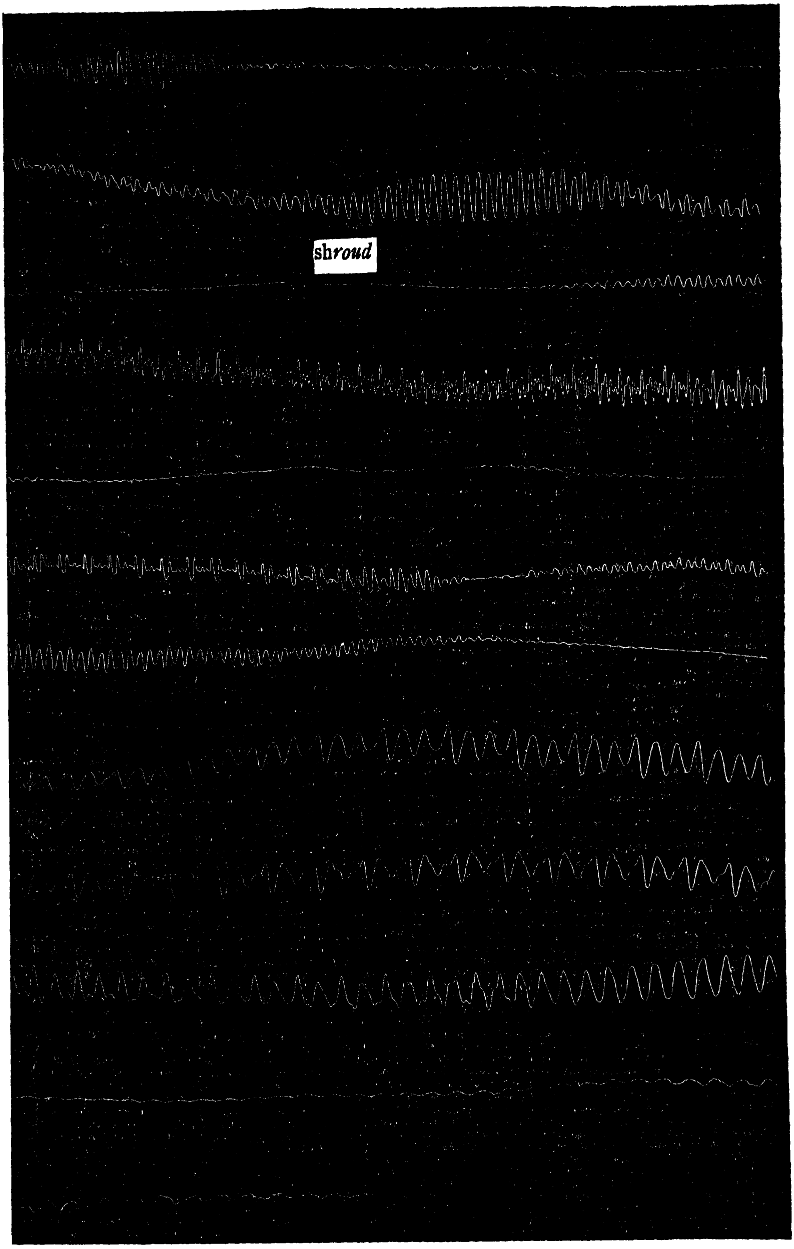


Cock Robin, Series II, Block I^A.

1^{mm}=0.0016^s.
1^{mm}=0.0007^s.



Cock Robin, Series II, Block I_B.

$1^{mm}=0.0016^{s}$.
$1^{mm}=0.0007^{s}$.